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October 11, 2016

VIA ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 12th Street S.W.
Washington D.C. 20554

Re: Oral *Ex Parte* Notice
GN Docket No. 14-177, IB Docket Nos. 15-256 and 97-95;
RM-11664 and 11773; and WT Docket No. 10-112

Dear Ms. Dortch:

On October 6, 2016, representatives of The Boeing Company ("Boeing") met with staff of the Federal Communications Commission ("Commission") to discuss the above-referenced proceedings and Boeing's further technical analysis regarding spectrum sharing between the Upper Microwave Flexible Use Service ("UMFUS") and next-generation broadband satellite communications systems in the V-band. The discussion tracked closely with the attached technical presentation and with Boeing's comments in response to the Commission's Further Notice of Proposed Rulemaking. A list of attendees is attached.

Thank you for your attention to this matter. Please contact the undersigned if you have any questions.

Sincerely,

Bruce A. Olcott
Counsel to The Boeing Company

Attachments

October 6, 2016 Ex Parte Meeting Attendees

Wireless Telecommunications Bureau

- Simon Banyai
- Matthew Pearl
- John Schauble
- Catherine Schroeder
- Blaise Scinto
- Jeff Tignor
- Charles Oliver
- Nancy Zaczek

International Bureau

- Jose Albuquerque
- Robert Nelson
- Kal Krautkramer

Office of Engineering and Technology

- Michael Ha
- Bahman Badipour
- Martin Doczkat
- Nicholas Oros
- Aspasia Paroutsas
- Barbara Pavon

Boeing Participants

- Bruce Chesley
- Audrey Allison
- Bruce Olcott
- Robert Vaughan
- Stephen Cowen (by phone)
- Preston Thomas (by phone)

Boeing Comments on Spectrum Frontiers Further Notice of Proposed Rulemaking

October 6, 2016

TOPICS

- **Boeing's NGSO FSS Satellite System**
- **Boeing's Spectrum Frontiers FNPRM Comments**
- **Broadband Digital Divide and Spectrum Requirements**
- **Uplink V-Band Sharing Proposals**
  - **FSS end user terminals and UMFUS systems**
  - **UMFUS and FSS Gateway coordination**
- **Downlink V-Band Sharing Proposals**
  - **37/39 GHz pfd level**
- **Comments on Other Bands**
  - **71-76, 81-86 GHz and Above 90 GHz**
  - **57.1-71 GHz aircraft use/operations**

Growth in Broadband Demand and the Digital Divide

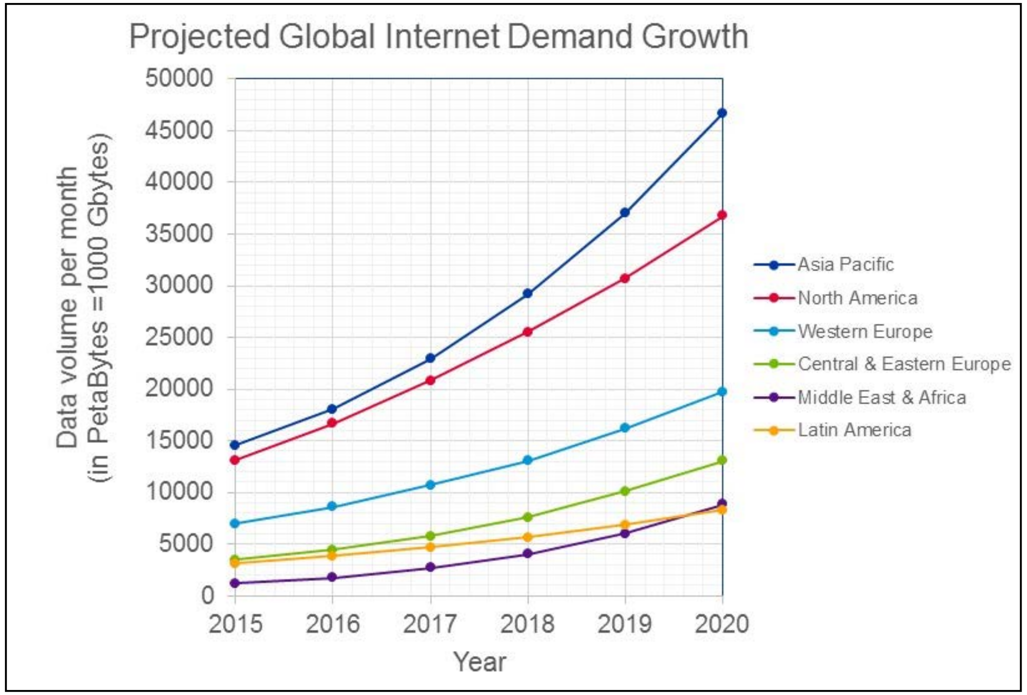
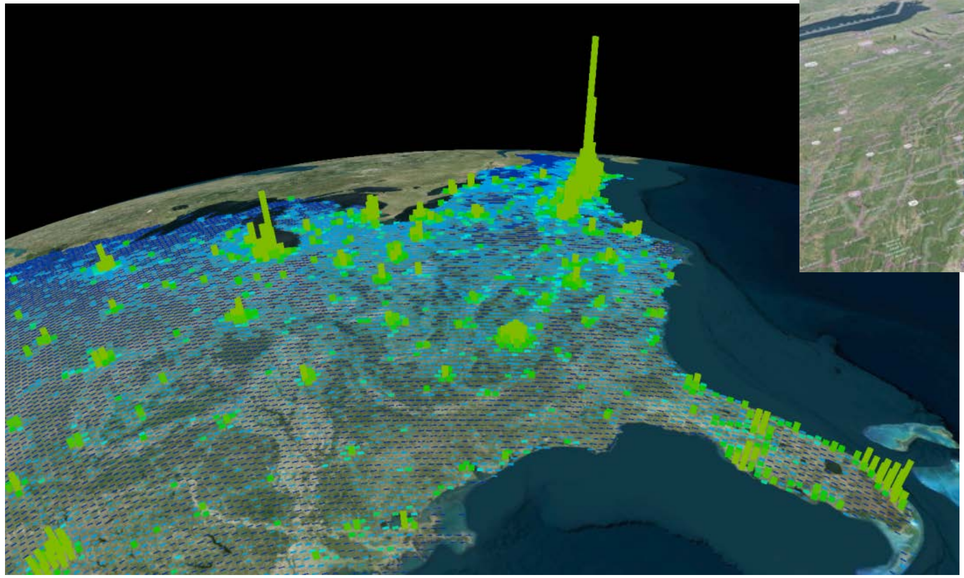
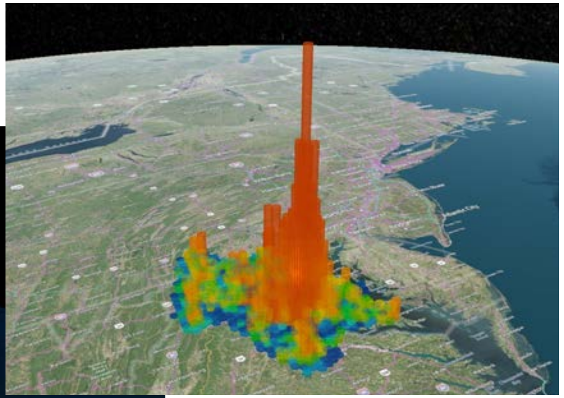


Figure II-2. Projected Global Internet Demand Growth (2017-2020)[1]



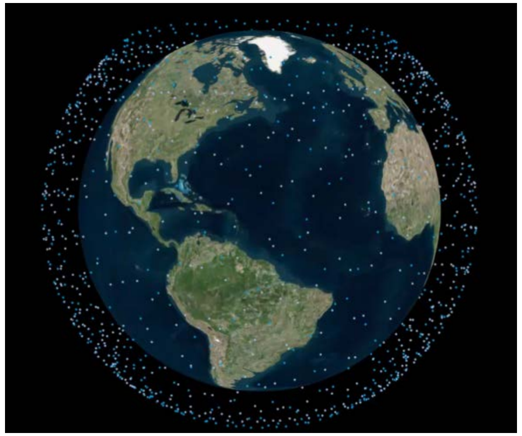


- **Broadband demand will continue to grow in all regions further aggravating urban/rural digital divide**

- **Satellite systems with sufficient spectrum can rapidly address the broad range of demand and permanently resolve urban/rural digital divide**

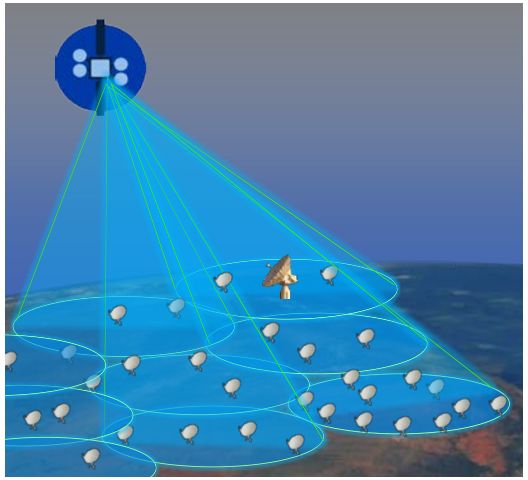
[1] Cisco Visual Networking Index Forecast and Methodology, 2015–2020, Table 8 (available at http://www.cisco.com/c/dam/en/us/solutions/collateral/service-provider/visual-networking-index-vni/complete-white-paper-c11-481360.pdf) ("*Cisco Visual Networking Index Forecast*").

Boeing Global Broadband System Overview



Global Constellation
Spacecraft Qty: 1396/2956
Orbit Altitude: ~1200 km
Orbit Inclinations: 45°, 55° & 88°

Provides Global Coverage



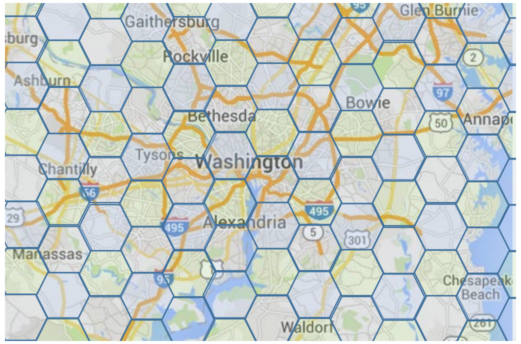
System Design

Broad Coverage LEO Satellites with Flexible Beam-forming Technology

Phased array antennas form robust links with high throughput and isolation and low side-lobe beams

Millimeter wave technology proven and deployed in government and commercial FSS and terrestrial systems

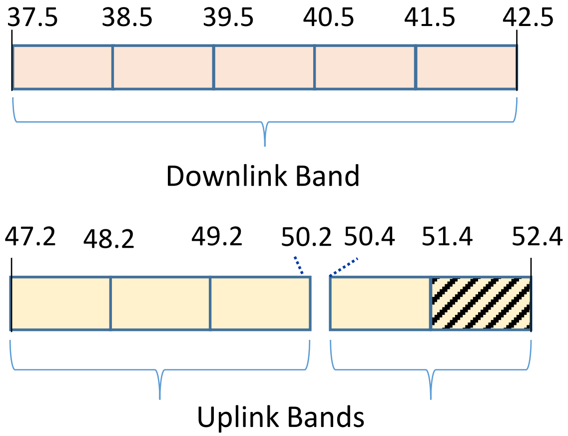
8 km cells over Washington DC



Service Density
3-Color (Time) reuse allows for very high throughput that is competitive to serve both urban and rural areas

Peak User Rates
Exceeds FCC's Broadband Goals
>25 Mbps Down / >3 Mbps Up

Broadband speeds are available to all global users



Frequency Plan

Each Beam uses all 5 GHz, dual polarization, up and down

Time domain division between adjacent cells

Gateways and user terminals share uplink and downlink bands

Broadband Demand Requires Access to 5 GHz of Paired V-band Downlink and Uplink Spectrum

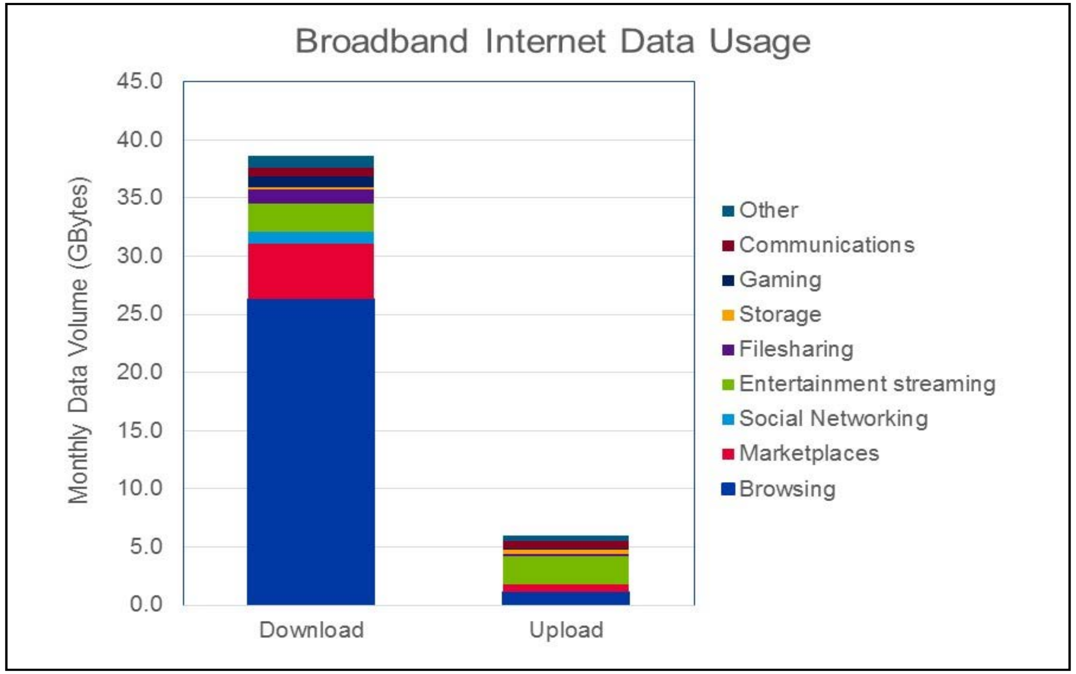


Figure II-1. Current Broadband Internet Data usage in Download and Upload directions[1]

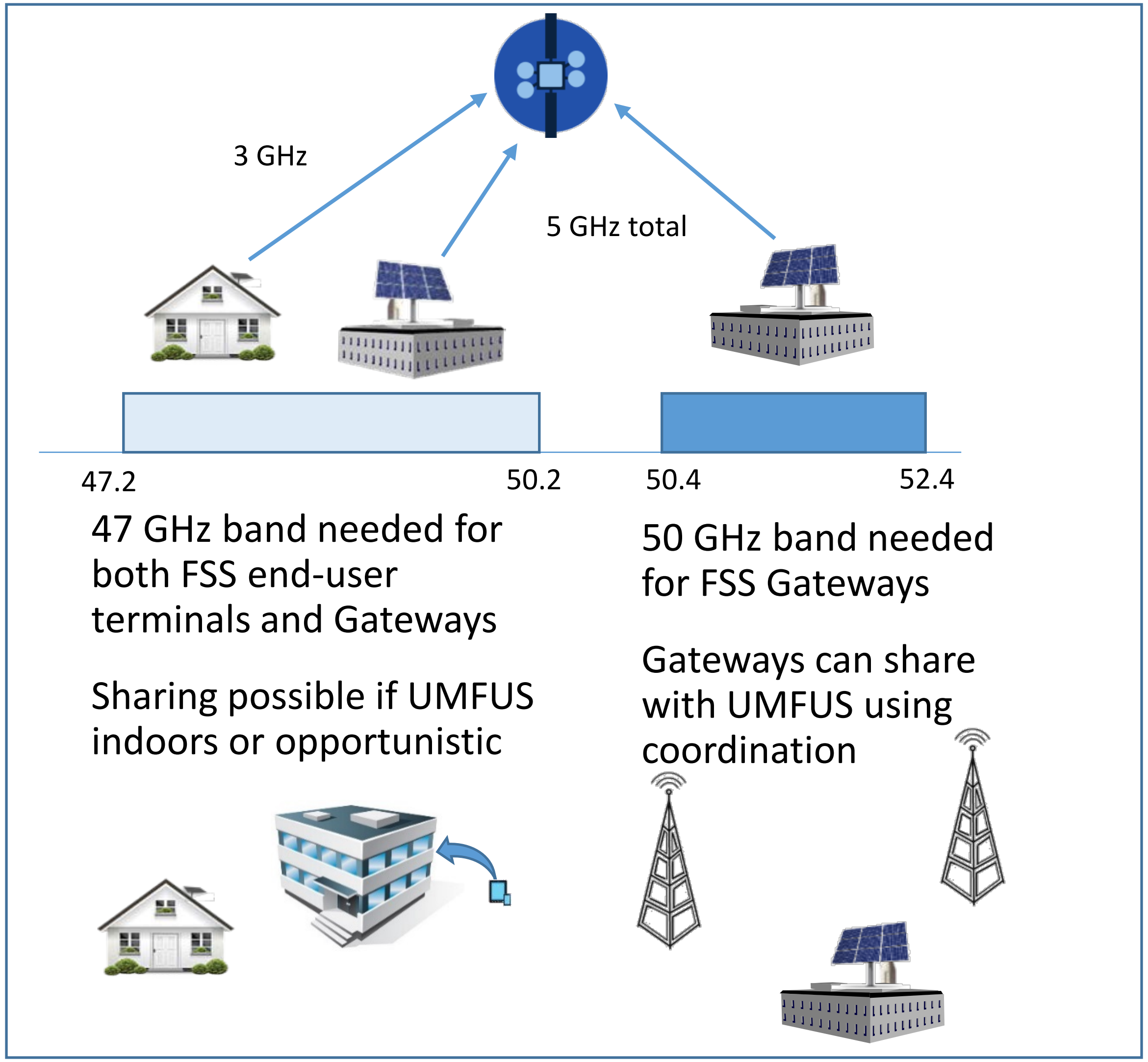
[1] Data derived from Sandvine Global Internet Phenomena Reports, June 2016, available at https://www.sandvine.com/trends/global-internet-phenomena/

Download/Upload Data Asymmetry	6	to 1
Boeing Satellite Bandwidth Usage Summary		
FWD/RET User Capacity Asymmetry	6	to 1
FWD User Downlink Bandwidth	5.0	GHz
FWD User Downlink efficiency	2.47	bps/Hz
RET User Uplink Efficiency	0.79	bps/Hz
RET Uplink User Spectrum needed	2.6	GHz
FWD Uplink GATEWAY spectrum needed	5.0	GHz

- Broadband Data usage is asymmetric (6 to 1 ratio)
- Downlink / forward spectrum efficiency is higher than uplink / return spectrum efficiency
  - User terminals are less capable transmitters (low power/size)*
  - Return link waveform has more overhead*
    (same as LTE/cellular systems)
  - Uplink rain losses are higher than downlink
- Additional spectrum needed for sharing between multiple satellite systems (both GSO and NGSOs)

Broadband Satellite Uplink Requirements

- **Boeing's Gateway uplinks and end user terminal uplinks can share the same 5 GHz**
- **Satellite end user terminals require 3 GHz of return uplink spectrum at 47.2-50.2 GHz**
  - **Can share if UMFUS located indoors or allowed outdoors on an opportunistic secondary basis**
- **Satellite systems require 5 GHz of Gateway uplink spectrum to service forward downlinks to satellite end user terminals**
  - **Boeing's satellite Gateways require access to entire 47.2-50.2 GHz and 50.4-52.4 GHz bands**
  - **Satellite Gateway locations should be coordinated with UMFUS systems on a first-in-time basis**

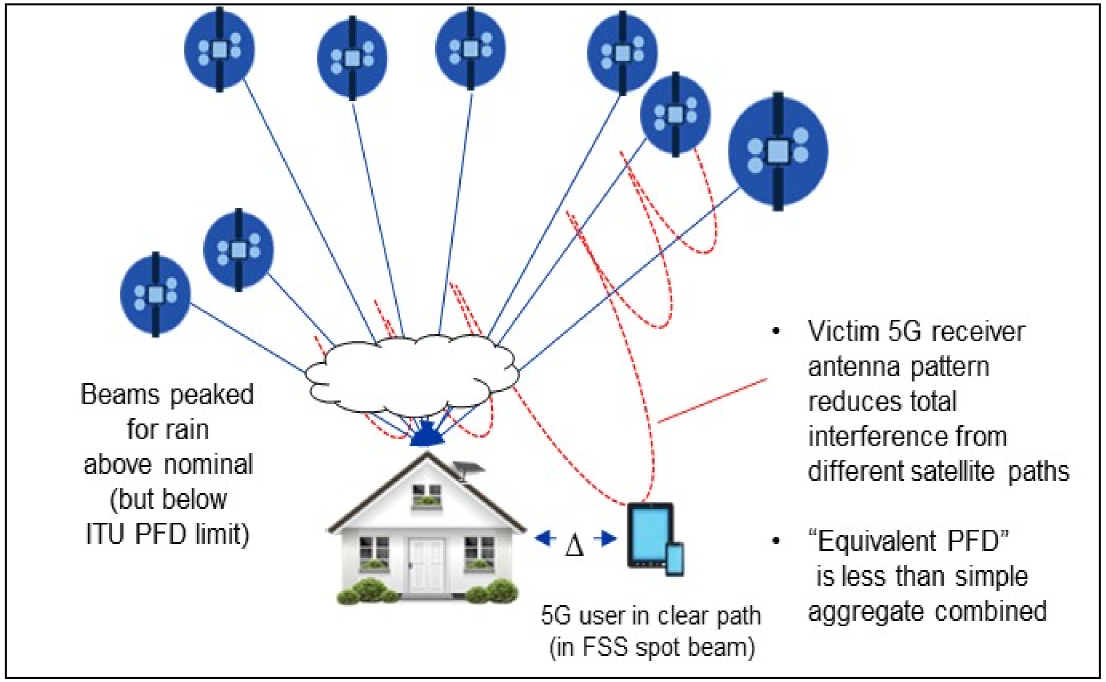


Uplink Sharing Is Best Served by Coordination

- **Boeing can locate its FSS Gateways outside core urban areas**
  - **Boeing's Gateways will likely affect approximately 0.1% of total U.S. population**
- **Boeing cannot site its Gateways pursuant to a 0.1% approach or using a limit of 1 or 3 in each county or Partial Economic Area**
  - **Boeing will require thousands of separate Gateway locations**
  - **Many PEAs will host significantly more than 3 Gateway locations**
  - **Boeing's Gateways will exceed 0.1% of population in some rural PEAs**
- **Satellite Gateways should be licensed outside core urban areas using first-in-time coordination**
  - **Each FSS Gateway location protected if brought into use within 1 or 2 years**
- **UMFUS base stations (or links) should be authorized in same manner**
  - **Each UMFUS site or link protected if brought into use within 1 or 2 years**

Broadband Satellite Downlink Requirements

- **Satellite systems need access to an entire 5 GHz of paired V-band spectrum to provide broadband services with high efficiency and high re-use**
- **Boeing's sharing proposals provide UMFUS and FSS shared access to the majority of the 5 GHz of paired V-band spectrum**
- **Broadband forward links to end users require:**
  - **Full access to 40.0-42.0 GHz band**
  - **Opportunistic Access to 37.5-40.0 GHz band**
  - **Opportunistic Access to 42.0-42.5 GHz band**
- **Boeing's studies demonstrate aggregate satellite downlinks in the 37.5-40.0 GHz band at ITU PFD levels will not harm UMFUS systems**



Downlink Operations up to ITU PFD Limit Has Negligible Impact on UMFUS Systems

BOEING

- **Boeing earlier presented substantial analyses demonstrating minimal degradation due to FSS operations up to ITU PFD limit**
  - **Worst-case, single satellite beams into various UMFUS receivers**
  - **With mobiles pointed directly at a satellite**
  - **With base stations upwards pointed to 35 degrees**
- **Boeing FNPRM comments extend analyses:**
  - **Statistical analyses with large numbers of satellites**
  - **Power control operation during rain fade conditions**
- **Updated results for multiple satellites align with prior worst-case assessments**

MOBILE USER CHARACTERISTICS				Broadside (horizontal Beam)						
Linear array dimension	Array Configuration	Total Elements	Peak Gain	Rolloff (relative gain) at 45-deg offset*	Absolute Gain at 45-deg offset	Satellite Interference Level after antenna gain	5G receiver Noise density	Interference to Noise ratio, I_{SAT}/N_{5G}		5G link degradation
(cm)			(dBi)	(dBr)	(dBi)	(dBW/MHz)	(dBW/MHz)	(dB)	(%)	(dB)
1.55	1x4 or 2x2	4	10.0	0.0	10.04	-148.2	-137.0	-11.3	7.5	0.31
3.10	1x6 or 2x3	6	11.8	0.0	11.80	-146.5	-137.0	-9.5	11.2	0.46
1.55	1x8 or 2x4	8	13.0	0.0	13.05	-145.2	-137.0	-8.2	15.0	0.61

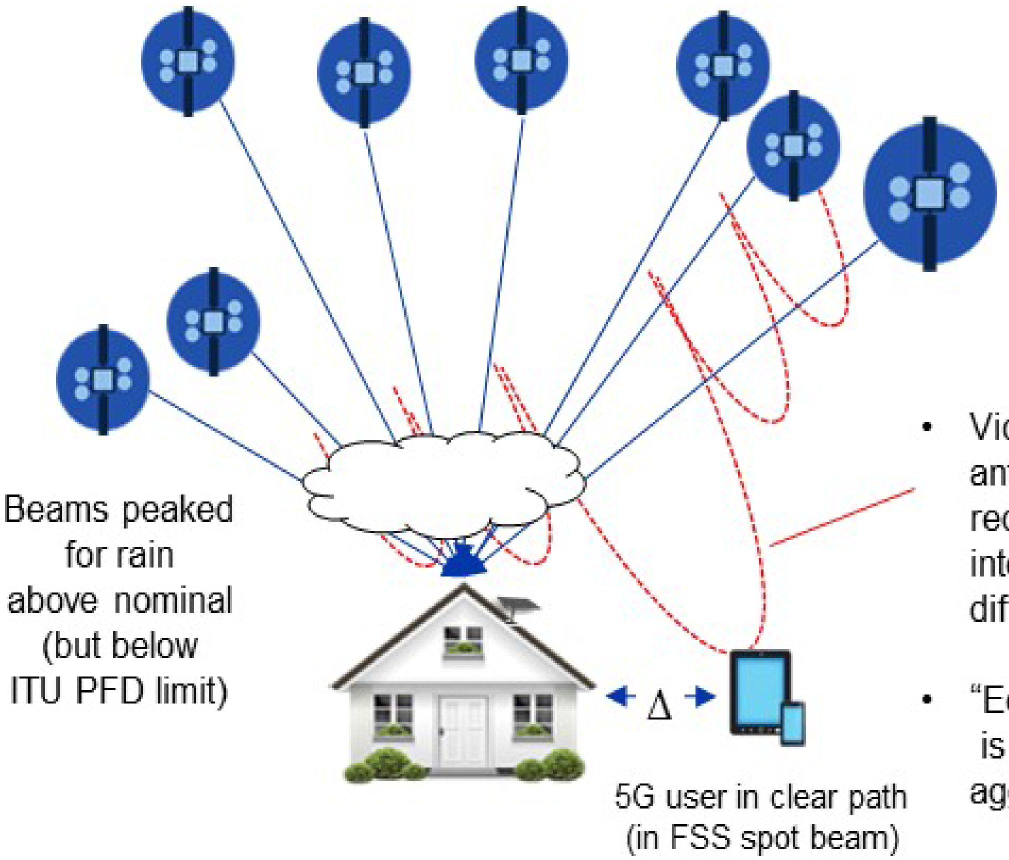
Table V-1 – Worst-case FSS interference into Mobile Handsets*
(with handset beams mis-pointed at satellite)

BASE STATION CHARACTERISTICS				35-degree scanned beam						
Linear array dimension	Array Configuration	Total Elements	Peak Gain	Rolloff (relative gain) at 45-deg offset	Absolute Gain at 45-deg offset	Satellite Interference Level after antenna gain	5G receiver Noise density	Interference to Noise ratio, I_{SAT}/N_{5G}		5G link degradation
(cm)					(dBi)	(dBW/MHz)	(dBW/MHz)	(dB)	(%)	(dB)
1.55	4x4	16	16.1	9.5	6.52	-151.7	-139.0	-12.8	5.3	0.22
3.10	8x8	64	22.1	13.1	8.97	-149.3	-139.0	-10.3	9.3	0.39
4.65	12x12	144	25.6	21.5	4.12	-154.1	-139.0	-15.2	3.0	0.13
6.20	16x16	256	28.1	22.6	5.53	-152.7	-139.0	-13.8	4.2	0.18
12.40	32x32	1024	34.1	24.5	9.60	-148.7	-139.0	-9.7	10.7	0.44

Table V-3 – Worst-case FSS Interference into Base Station – 35 Degree Upwards Scanned Beams

FSS operation up to ITU PFD limit and appropriate "ePFD" limits support sharing 37/39 GHz and 42 GHz bands has negligible impact (less than 0.6 dB) on UMFUS operations

Equivalent PFD (“ePFD”) Analyses are Appropriate for Calculating FSS to UMFUS Interference



- Victim 5G receiver antenna pattern reduces total interference from different satellite paths
- “Equivalent PFD” is less than simple aggregate combined

$$ePFD = 10log_{10}\left(\sum_{k=1}^{Nsats} 10^{\frac{(G_r^k(\theta_k,\phi_k)+PFD_k)}{10}}\right) - (G_{r-pk})$$

N_{sats} = Number of total NGSO satellites radiating beams at the particular ground point
PFD_k= incident PFD of the k[th] NGSO satellite at the ground point in dBW/m2/MHz
$G_r^k(\theta_k,\phi_k)$= Gain of the 5G victim receiver antenna in the direction toward the kth NGSO satellite, in dBi
G_{r-pk}= Peak gain of the 5G victim receiver (usually G_r (0,0) at boresight), in dBi

$$INR_{dB} = [ePFD + G_{r\text{-}pk} - 10\log_{10}(4\pi/\lambda^2) - k - T_r]$$

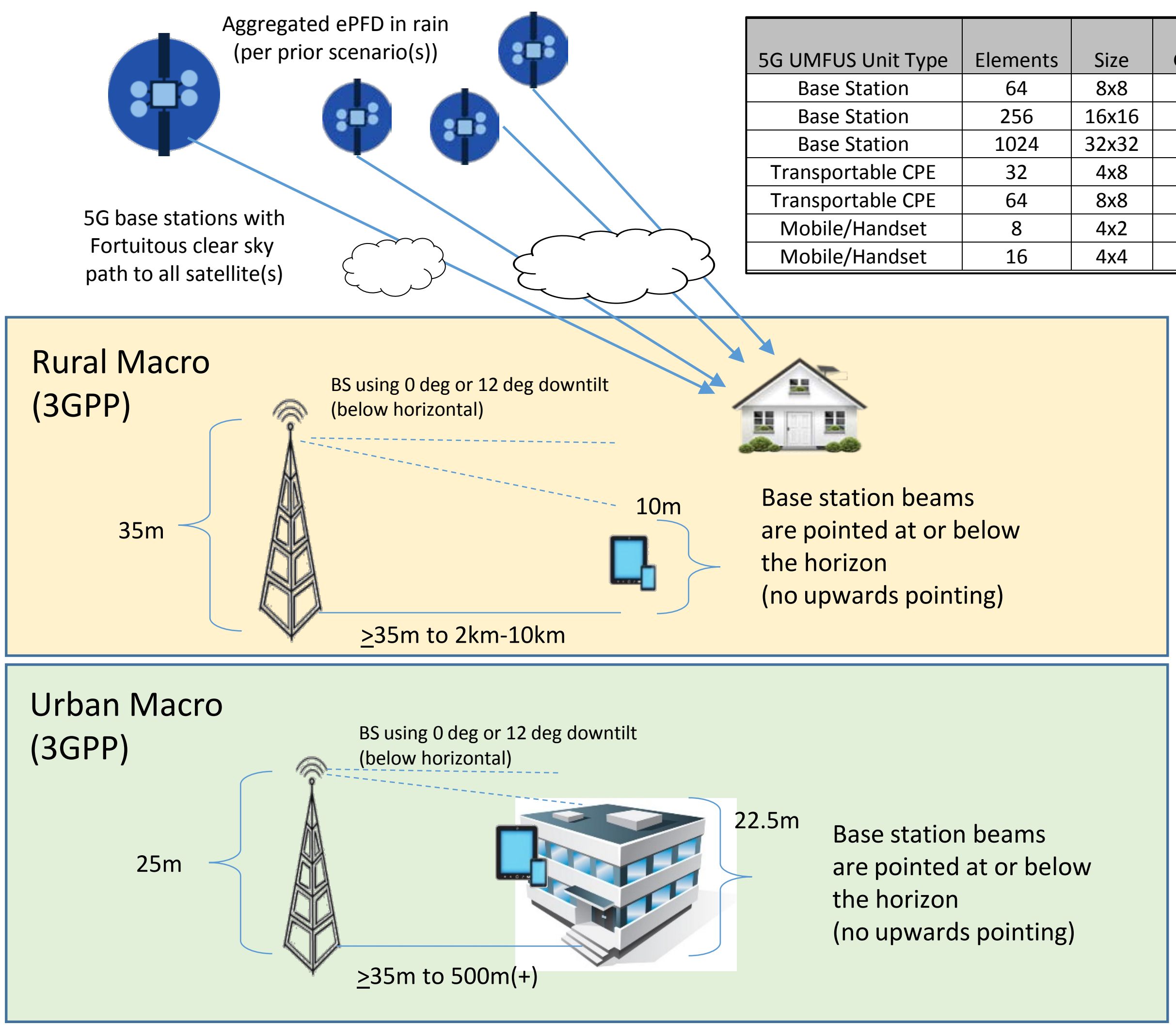
$$(I/N)_{deg} = 10\log_{10}(10^{(INR/10)}+1)$$

λ = wavelength in m; λ ~= (0.3/F_c) where F_c is in GHz
G_r = Isotropic gain of the 5G receiver in the direction of the arriving PFD signal, in dBi
K = Boltzmann’s constant, -228.6 dB W/K-Hz
T_r = 5G receiver noise temperature in dB/K, calculated as $10\log_{10}(T_b+290*[10^{(NF/10)}+1])$ where T_b= background temperature (usually 290K for terrestrial background and/or rain) and NF = noise figure of the 5G receiver in dB

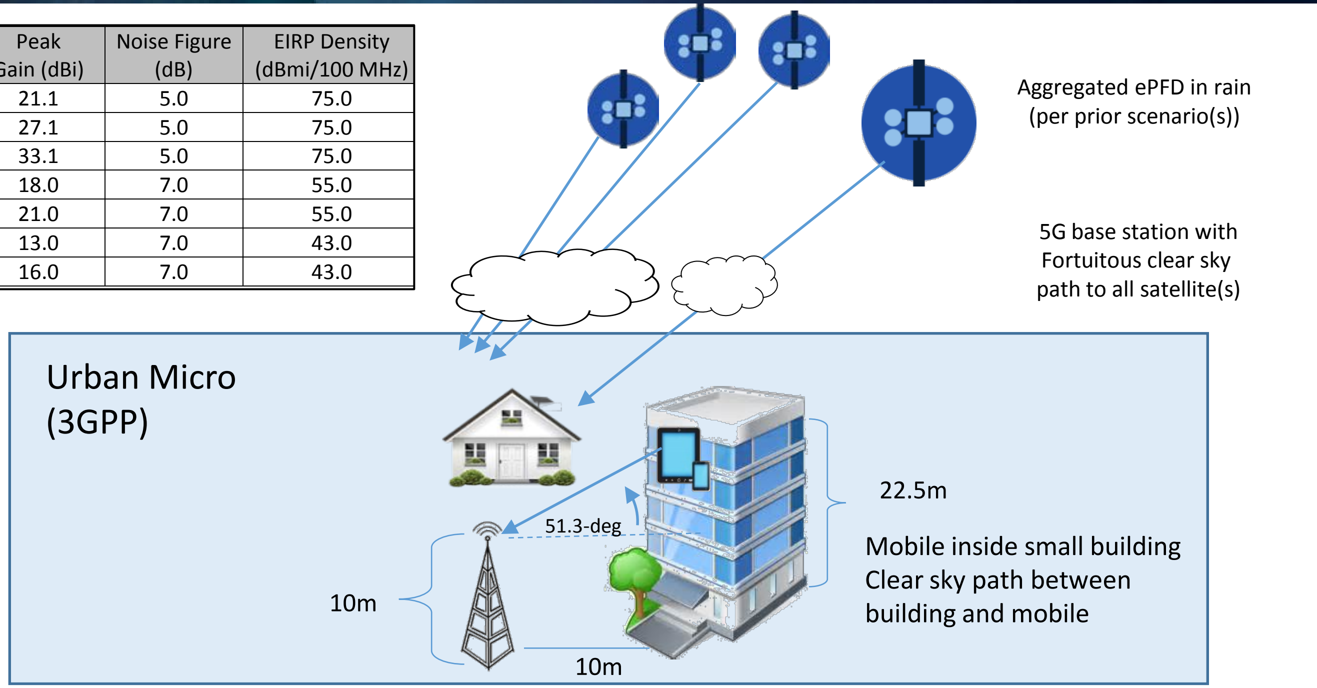
- **ePFD methodology used by FCC for Ku-band NGSO rules and correctly models FSS/UMFUS sharing**
- **Worst-case conditions – rain fade to satellite receivers and clear sky path to UMFUS receivers**

Highly Representative UMFUS Receivers and Scenarios are Used in ePFD Analyses

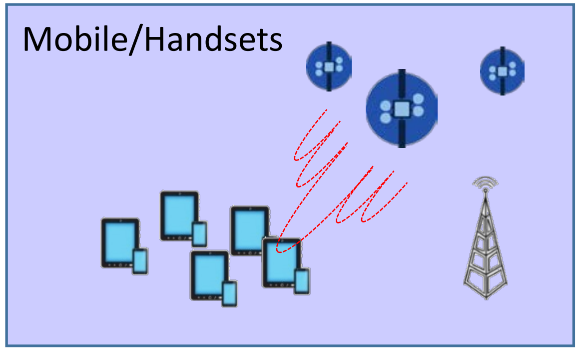
5G UMFUS Unit Type	Elements	Size	Peak Gain (dBi)	Noise Figure (dB)	EIRP Density (dBmi/100 MHz)
Base Station	64	8x8	21.1	5.0	75.0
Base Station	256	16x16	27.1	5.0	75.0
Base Station	1024	32x32	33.1	5.0	75.0
Transportable CPE	32	4x8	18.0	7.0	55.0
Transportable CPE	64	8x8	21.0	7.0	55.0
Mobile/Handset	8	4x2	13.0	7.0	43.0
Mobile/Handset	16	4x4	16.0	7.0	43.0



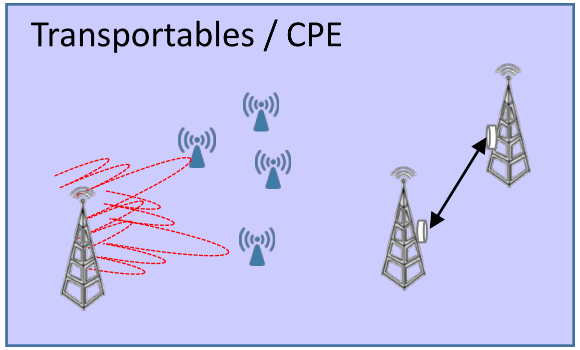
Random pointed beams – no upwards pointing sectors



Random pointed or user pointed beams – upwards pointing to 60-deg

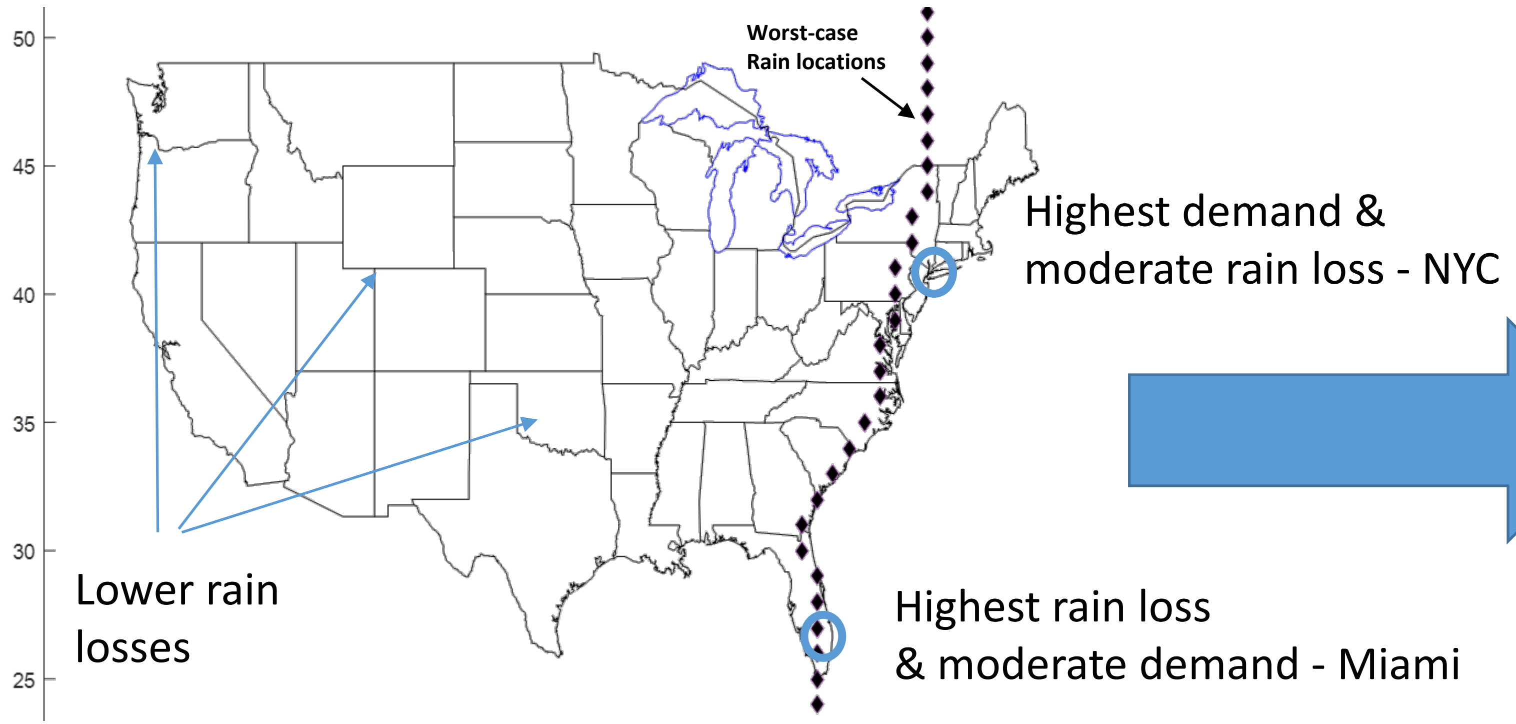


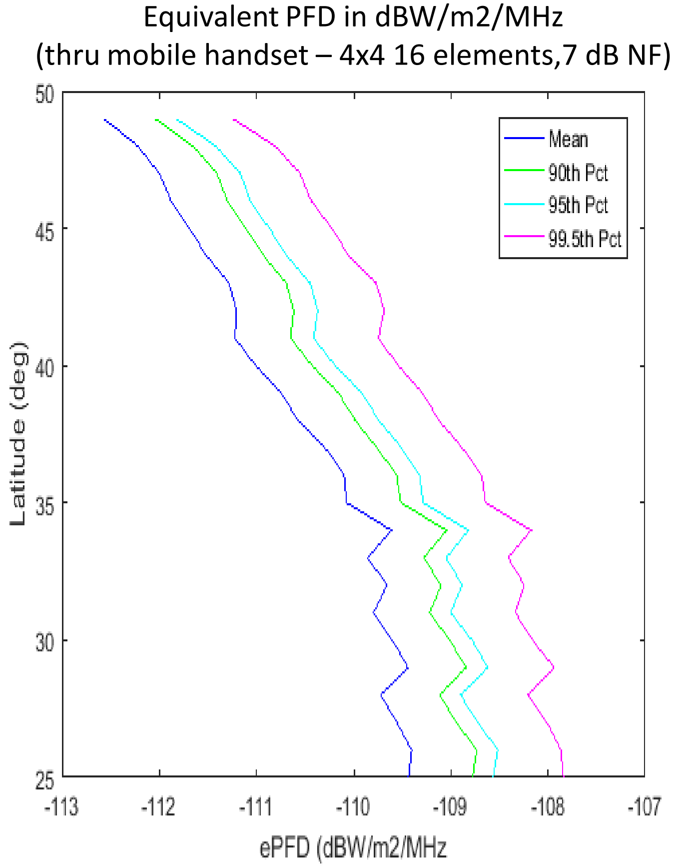
Random pointed beams – mispointed at a satellite



Pointed at base station

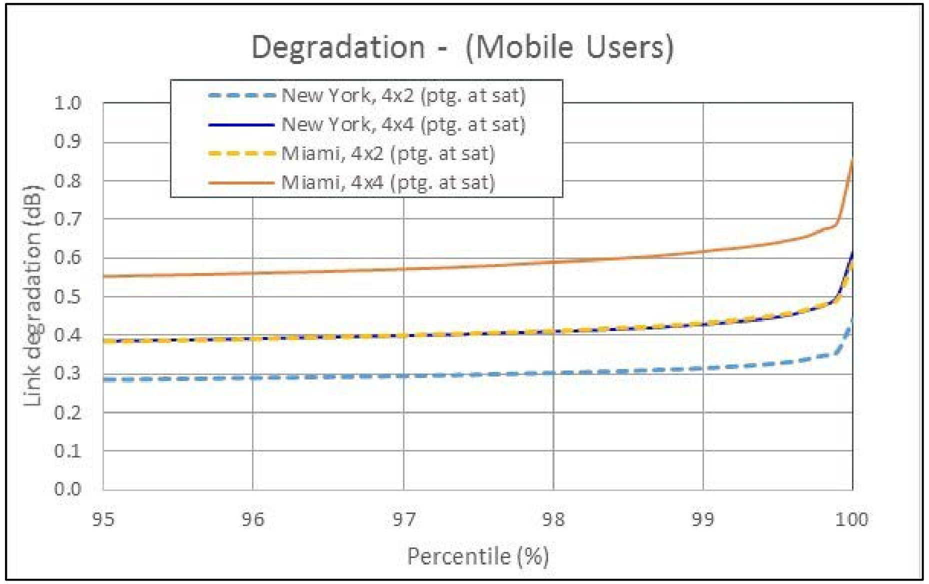
NGSO FSS Operations and ePFD Assessed in Worst-Case Rain Fade Conditions

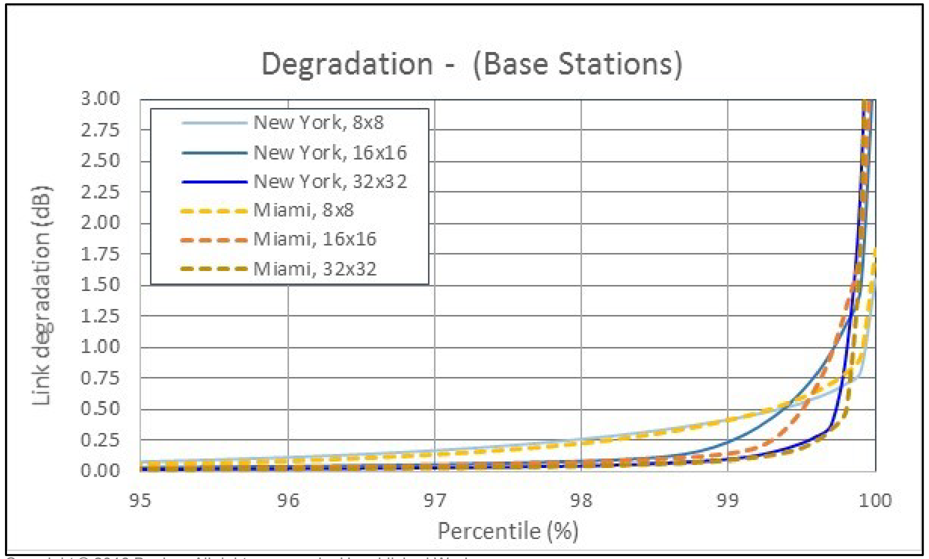




- **Worst-case assumptions combine highest rain fade locations and highest demand areas**
- **Boeing completed full U.S. assessment, with points showing greatest rain/demand combinations**

NGSO Operations in Worst-Case Rain Conditions has Negligible Impact on UMFUS



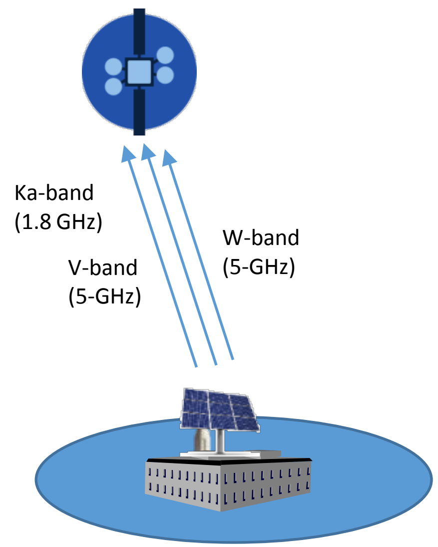


Scenario	5G receiver	Location	ePFD (dBW/m2/MHz)		Link degradation (noise increase), dB	
			99%	99.5%	99%	99.5%
1 – Mobile Users	Handset 4x2	New York	-108.1	-107.9	0.31	0.33
	Handset 4x4		-109.7	-109.5	0.43	0.45
1 – Mobile Users	Handset 4x2	Miami	-106.7	-106.5	0.43	0.45
	Handset 4x4		-108.1	-107.8	0.62	0.64
2a – Transportable CPE	CPE (8X8)	New York	-128.2	-127.5	0.020	0.022
2b – Transportable CPE	CPE (8x8)	Miami	-127.5	-126.7	0.022	0.026
3a - Base Stations (random ptg)	64 elem (8x8)	New York	-116.5	-115.0	0.42	0.55
	256 elem (16x16)		-125.1	-120.4	0.24	0.65
	1024 elem (32x32)		-135.0	-131.2	0.10	0.23
3a - Base Stations (random ptg)	64 elem (8x8)	Miami	-116.4	-115.0	0.42	0.60
	256 elem (16x16)		-127.0	-121.5	0.15	0.50
	1024 elem (32x32)		-135.2	-132.0	0.10	0.19
3b - Base Stations (Urban Micro)	64 elem (8x8)	New York	-129.3	-128.5	0.023	0.027
	256 elem (16x16)		-127.0	-136.0	0.016	0.018
	1024 elem (32x32)		-144.2	-143.2	0.012	0.014
3b - Base Stations (Urban Micro)	64 elem (8x8)	Miami	-129.0	-128.0	0.026	0.031
	256 elem (16x16)		-136.1	-135.5	0.018	0.022
	1024 elem (32x32)		-135.4	-142.6	0.014	0.017

Impact to UMFUS is less than 0.65 dB in all cases with a 99.5% confidence level using improbable worst-case conditions – rain fade to satellite receivers and clear sky to UMFUS

Studies Should be Completed on Higher Frequency mmW Bands Before Usage Decisions are Made

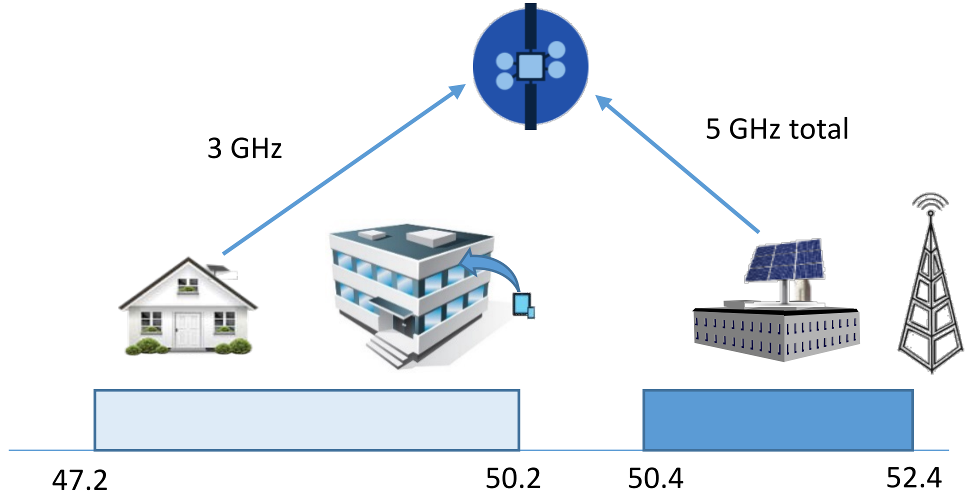
- **Rapid technological innovation of mmW components and systems makes satellite usage of 70 and 80 GHz bands (or even above 90 GHz) a likely reality in the near future**
- **Atmospheric and rain attenuation at higher mmW bands makes satellite usage more power-intensive, particularly for small user terminals**
- **However, W-band (71-76 GHz and 81-86 GHz) is well suited for such functions as satellite gateway feeder links**
- **All appropriate for shorter range services such as high altitude platform based services ("HAPS")**
- **These bands are under study by the ITU with groups formulating comments and recommendations for WRC-19**
- **Boeing urges the Commission to refrain from adopting any measures that could preclude the operation of satellite or HAPS systems in these higher spectrum bands**



- Satellite feeder link usage (multi-band GWs)
- Same #gateway locations

Summary and Recommendations – V-band Uplink

- **Recommend 47.2-50.2 GHz be identified for FSS services as primary usage with UMFUS systems limited to indoors or on an opportunistic outdoor basis**
- **Recommend 50.4-52.4 GHz be available for UMFUS on a coordinated shared basis with licensed FSS Gateways**
- **UMFUS base stations and FSS Gateway coordination methods via rural siting and location-based sharing**
  - **Less restrictive than PEA-based approach but can satisfy UMFUS deployment goals**

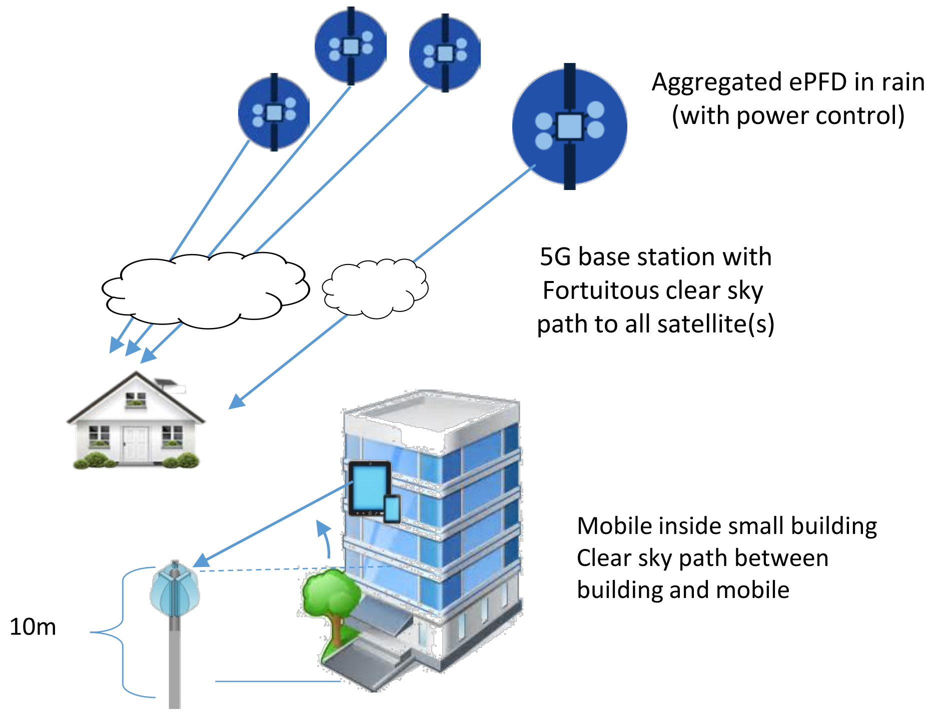


- FSS end-user terminals (primary)
- UMFUS outdoor use (secondary/opportunistic)
- UMFUS indoor usage

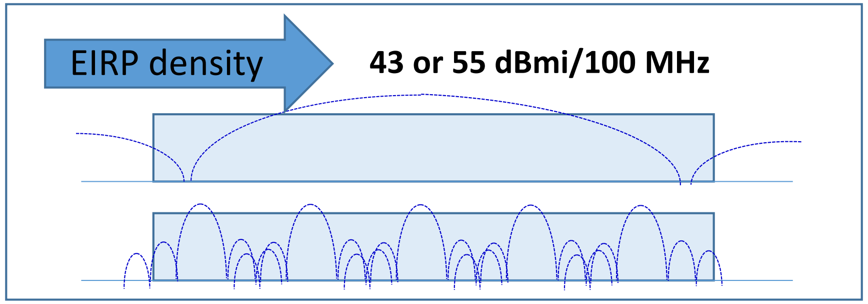
- UMFUS outdoor use (co-primary)
- FSS Gateways (co-primary)
- FSS Gateways only outside of metropolitan zones
- Coordinated rural usage by location and first-in time

Summary and Recommendations – V-band Downlink

- **Recommend authorization of FSS end user terminals in the 37.5-40.0 GHz band**
- **Recommend allowing FSS operations up to ITU PFD limit with UMFUS-specific ePFD limits**
- **Recommend shared UMFUS and FSS authorizations for the 42.0-42.5 GHz band**
- **Concur with Commission's EIRP versus antenna height FNPRM limits**
- **Recommend all UMFUS devices be subject to maximum EIRP density (FNPRM proposal)**



<0.65 dB degradation (all cases)

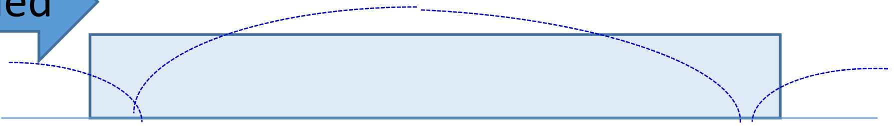


EIRP Scaling of UMFUS Devices is Critical to Sharing

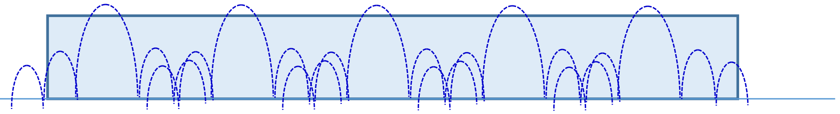
- **Order adopted EIRP limits for all UMFUS devices**
- **Only base station maximum EIRP <u>density</u> was specified; other UMFUS devices specified maximum EIRP only**
- **All analyses and link budgets presented in support of the Order assumed EIRP scaling for handset/mobiles**
    - **Strong UMFUS performance demonstrated using authorized EIRP as a maximum EIRP density with bandwidth scaling**
- **Boeing's interference analyses also used UMFUS device EIRP as a maximum density**
- **Outdoor operations using EIRP without a maximum density (or scaling) would greatly increase UMFUS interference to all other users (terrestrial FS, Federal FS, FSS, and RAS)**
- **Indoor uses may employ different EIRP density approaches**

Recommended

43 or 55 dBmi/100 MHz

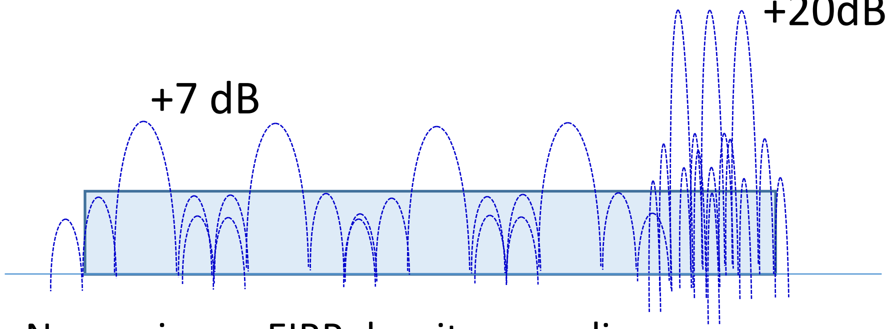


TDD-like operation



Mixed FDD/TDD-like operation with EIRP scaling

Mixed subnets with no constraints



No maximum EIRP density or scaling – high increase in interference density from mobile or transportable users located outdoors

Concur with need for maximum EIRP density limit for all outdoor UMFUS devices